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V. QUITTNER

2,659,016

OPERATION OF X-RAY TUBES

Filed July 19, 1951

2 Sheets-Sheet 1

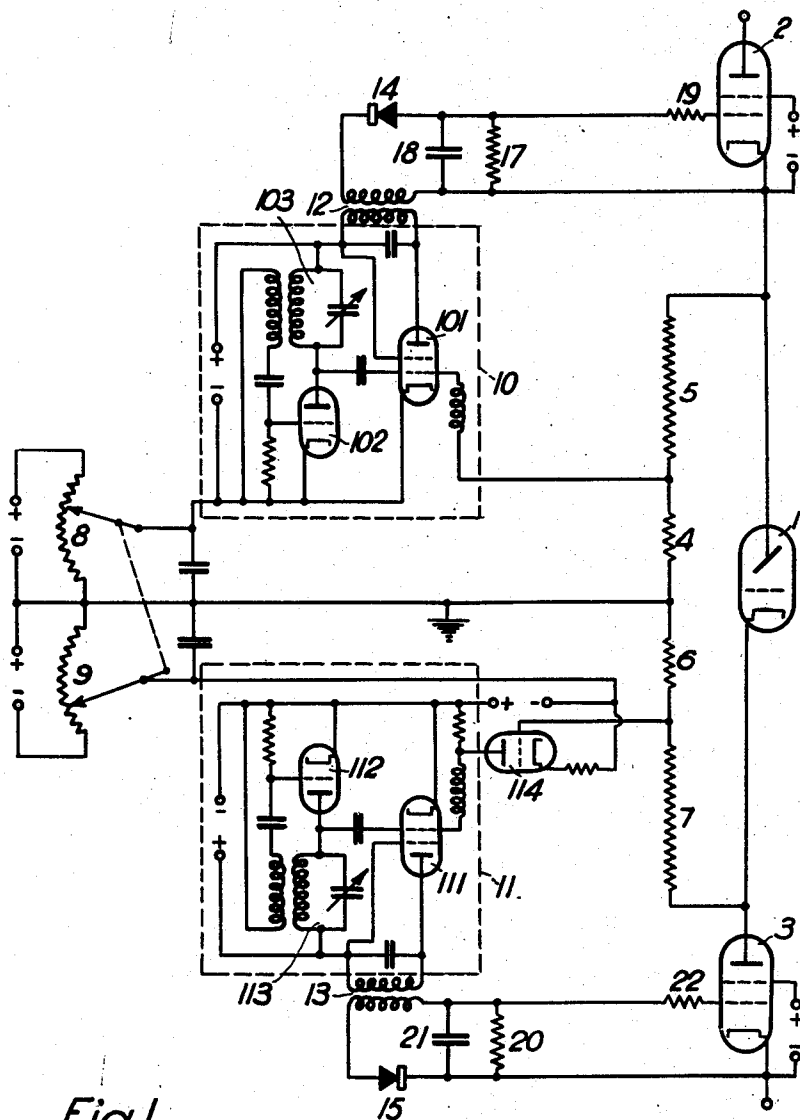


Fig. 1.

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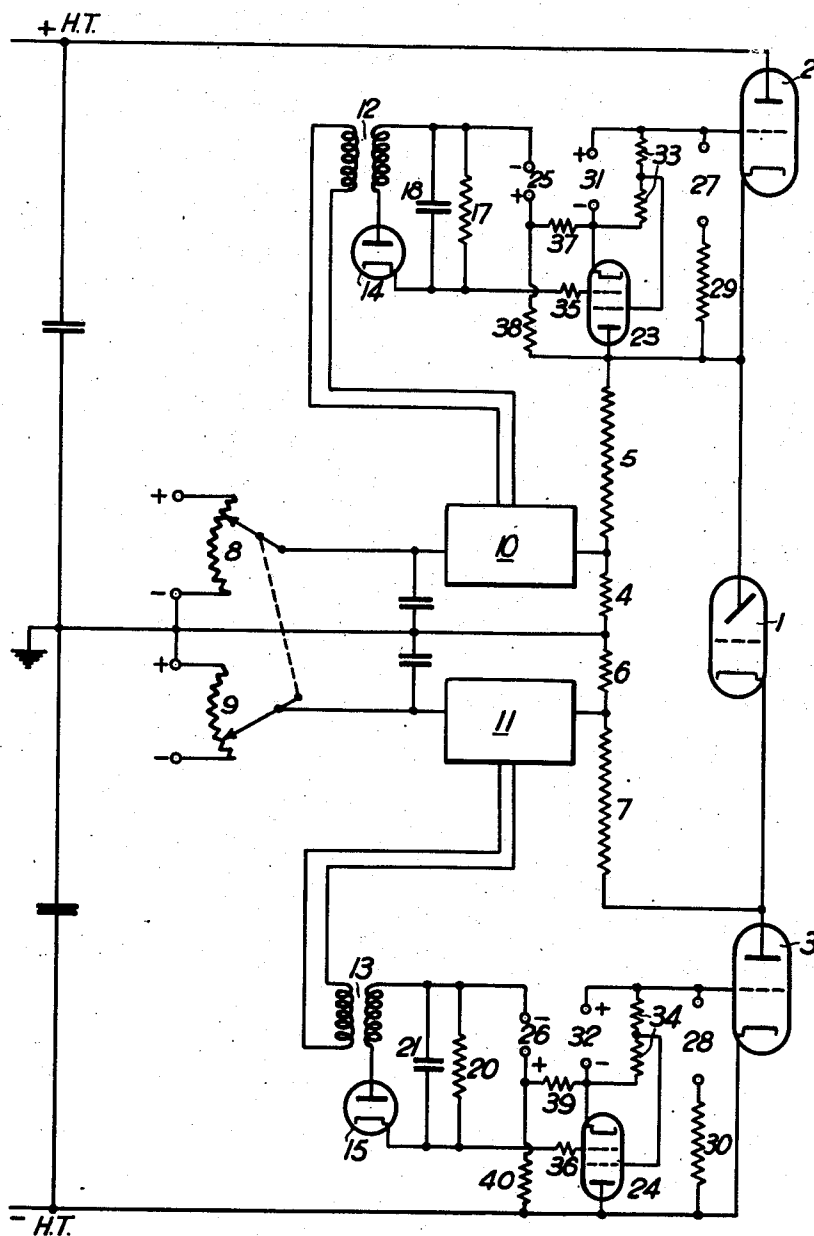


Fig. 2.

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OPERATION OF X-RAY TUBES

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Application July 19, 1951, Serial No. 237,560

Claims priority, application Great Britain
July 22, 1950

5 Claims. (Cl. 250-103)

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A known way of switching on and off an X-ray tube is by the use of a grid-controlled switch tube in series with it, the grid bias of the switch tube being governed by a switch in a low voltage circuit. A well insulated transformer is a convenient means of transferring the control to the high tension circuit of the X-ray tube, and therefore alternating currents have been used in the low tension circuits with rectifiers in the transformer secondary circuits. To obtain prompt response in the high tension circuits to a switching operation in a low tension circuit a high frequency alternating current has been employed.

According to the use to which an X-ray tube is put the voltage applied to it may need to be adjustable over a wide range. Also in the many uses in which the X-ray tube is required to yield rays of substantially constant hardness, it is desirable that the voltage applied to the tube shall be kept constant notwithstanding variations of mains voltage or discharge of condensers from which the tube supply is drawn.

The present invention is concerned with circuits for operating an X-ray tube, that is to say both switching it on and off and also adjusting or maintaining constant the voltage applied to the tube. According to the invention a high frequency generator having its output controlled by a voltage tapped from a potentiometer connected across the X-ray tube or connected between an electrode of the X-ray tube and earth supplies through a high frequency transformer, a rectifier and a smoothing circuit the grid bias of a grid-controlled switch tube in series with the X-ray tube, the rectifier being so set that increase in the voltage across the X-ray tube or in the potential relative to earth of the electrode connected to the potentiometer modifies the bias on the grid of the switch tube so as to reduce the current through it. The switch tube must be capable of carrying the maximum current required in the X-ray tube and of withstanding the supply voltage of the X-ray tube or the potential of its electrode relative to earth; and the operating circuit must be capable of increasing the grid bias from a negative value sufficient to cut off current through the tube under any condition of operation to a value at which the tube can pass the maximum current required by the X-ray tube. Where there is a high potential difference between the low voltage circuits and the switch tube they control, as will usually be the case, the high frequency transformer must have adequate insulation between its windings to withstand it.

While adjustment of the voltage across the

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X-ray tube could be made by varying the position of the potentiometer tapping, it is preferable, since at least one terminal of the potentiometer is at a high voltage relatively to earth while the X-ray tube is working, to immerse the whole of the potentiometer in oil so that its ratio is unaffected by temperature changes, to provide an independent source of adjustable voltage at the control desk, and to control the high frequency generator by the difference between this adjustable voltage and that tapped from the potentiometer.

If the amplification occurring in the high frequency generator and in the switch tube is not alone sufficient, the control may be rendered more sensitive by interposing an amplifying tube between the secondary winding of the high tension transformer and the grid circuit of the switch tube. In this case a negative cut-off voltage may be applied to the switch tube through a high resistance, and a positive bias may be applied to it through the cathode-anode circuit of the auxiliary amplifier. When the amplifier is biased to cut-off only the negative bias is operative; when it is conductive part of its anode current flows through the high resistance and the total bias can become positive.

For the sake of equalising the potentials to earth of both terminals of the X-ray tube and thereby reducing them to the least value possible, and in order wholly to isolate the X-ray tube from high tension when it is switched off, it is preferable to employ two switch tubes one on each side of the X-ray tube, as described in the specification of my application Ser. No. 237,559, filed July 19, 1951, and the construction of the switch tubes is much simplified if they have to deal with only half the high tension supply voltage. Embodiments of the invention using two switch tubes are illustrated by the accompanying diagrams of connections. It will be seen that to use one switch tube only is to dispense with one half of the control circuits shown.

Fig. 1 shows a simple form of the invention;

Fig. 2 shows the use of amplification in the control circuits.

In Fig. 1 the X-ray tube is indicated by 1, and the two switch tubes by 2 and 3 respectively. For controlling X-ray tubes which have only to take a small current for instance for X-ray tubes used for crystallographic investigations, the switch tubes may be triodes. As a rule it will be convenient to use beam tetrodes as indicated in the diagram or pentodes for the sake of their higher amplification. Between the X-ray tube

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electrodes and earth are connected potentiometers or tapped resistances 4, 5, and 6, 7. These will usually be immersed in oil so that it is inconvenient to vary the tappings. Instead the voltage drawn from each potentiometer is balanced against a steady but adjustable low voltage drawn from a source 8, 9 respectively; these sources have a common earthed terminal. The means of adjustment of the two sources are ganged so that a single control knob on the control panel of the apparatus serves to vary both to corresponding extents.

The control voltages so obtained in a low potential circuit, in part by manual setting of the sources 8, 9, and in part from the X-ray tube itself, are required to govern the bias of the switch tubes in a high potential circuit. The control voltages are employed to govern the output of high frequency generators 10 and 11, in any manner usual in modulation for communication purposes. In the scheme shown the voltage across the resistance 4 is applied to the grid and the voltage of the source 8 to the cathode of a tube, for instance an amplifying tube 101, in the high frequency generator 10, so that the difference of the two voltages is the grid bias of the tube. Tube 101 amplifies the output of an oscillator comprising a tube 102 having a tunable anode circuit 103 coupled to its grid in a well-known manner. Similarly the difference between the voltage across resistance 6 and that of source could govern the output of the correspondingly numbered generator 11. The generators 10, 11 supply transformers 12, 13 respectively, which are high frequency transformers with adequate insulation between their windings to withstand the potentials at which the switch valves operate. The transformers apply grid bias to the respective switch valves through rectifiers 14, 15 and smoothing elements 17, 18, 19 and 20, 21 and 22.

But the voltages applied to the generator 10 are of opposite sign to those applied to the generator 11; yet a chance increase in the voltage between either X-ray tube electrode and earth must increase the negative bias on the corresponding switch tube. This may be taken care of either by including a source of steady negative bias in the grid circuit of one switch tube, or by making the generators 10, 11 differ in the respect that increase in the positive tapped bias of the one and increase in the negative tapped bias of the other alike increase the generator output. In the diagram shown a reversing tube 114 changes the sign of the bias applied to tube 111.

Whatever the means employed to transfer the control from a low potential circuit to the X-ray tube circuit, it is important that it should introduce as little delay as possible or an oscillation of X-ray tube voltage may be set up.

A large part of the circuit of Fig. 2 is substantially the same as Fig. 1, and being marked with the same references needs no further description. The bias obtained from the transformers 12 and 13 is not applied directly to the grids of the switch tubes 2 and 3, but to auxiliary amplifier tubes 23, 24 which in turn control the bias on the switch tubes. Negative bias sufficient, in the absence of any modulation of the high frequency generator output, to render the auxiliary tubes non-conductive is applied to them by sources 25, 26. Negative bias sufficient to make the switch tubes, 2, 3, non-conductive so long as the auxiliary tubes 23, 24 are non-conductive, is supplied by sources 27, 28, connected between grid and cathode of the switch tubes in series with

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high resistances 29, 30. The auxiliary tubes 23, 24 are connected between cathode and grid of the respective switch tubes 2, 3 in series with sources of positive bias 31, 32. The auxiliary tubes 23, 24 are shown as screen grid tubes, taking screen grid voltage in usual manner from potentiometers 33, 34. The usual grid circuit resistances 35, 36 protect the tubes against excess current. Resistances 37, 38 and 39, 40 provide negative feed back for the auxiliary tubes to reduce the change in shape of their amplification characteristics as between the conditions of negative and positive bias on the switch tubes.

It will be seen that so long as the auxiliary tubes are biased to cut-off the switch tubes are also biased to cut-off. When current flows through the auxiliary tubes and the resistances 29, 30, the negative bias on the switch tubes is reduced and current begins to flow through them and the X-ray tube. As the bias on the auxiliary tubes varies further in the positive direction the bias on the switch tubes becomes positive and grid current flows. When the switch tubes are again biased to cut-off the X-ray tube is isolated and the charge on its supply leads is instantly dissipated through the potentiometers 4, 5 and 6, 7.

I claim:

1. A circuit for operating an X-ray tube, comprising a grid-controlled switch tube in series with the X-ray tube, a high frequency generator, a potentiometer connected to a terminal of the X-ray tube and to said high frequency generator applying to said generator a modulation dependent on the potential of at least one electrode of the X-ray tube, a high frequency transformer having its primary winding in the output circuit of said high frequency generator, and a rectifier and smoothing circuit connecting the secondary winding of said transformer to the grid and cathode of said switch tube.

2. A circuit for operating an X-ray tube, comprising a grid-controlled switch tube in series with the X-ray tube, potentiometer means connected with at least one of the electrodes of the X-ray tube and deriving therefrom a low stabilising voltage dependent on the potential of said electrode, and control transmitting means including a low voltage high frequency generator connected with said potentiometer means, and a transformer coupling said high frequency generator to the grid of said switch tube to apply thereto a voltage dependent on said stabilising voltage.

3. A circuit for operating an X-ray tube, comprising a grid-controlled switch tube in series with the X-ray tube, potentiometer means connected to at least one of the electrodes of the X-ray tube to derive therefrom a low stabilising voltage dependent on the potential of the electrode, an adjustable source of regulating voltage at low tension, and control transmitting means including a low voltage high frequency generator connected with said potentiometer means and said source and a transformer coupling said high frequency generator to the grid of said switch tube to apply thereto a voltage dependent on said stabilising voltage and said regulating voltage.

4. A circuit for operating an X-ray tube, comprising a grid-controlled switch tube in series with the X-ray tube, an auxiliary tube controlling the grid voltage of said switch tube, a high frequency generator, a potentiometer connected to at least one electrode of the X-ray tube and to said high frequency generator to apply to the latter a modulation dependent on the poten-

tial of said electrode, a high frequency transformer having its primary winding in the output circuit of said high frequency generator, and a rectifier and smoothing circuit connecting the secondary winding of said transformer to the grid 5 and cathode of said auxiliary tube.

5. A circuit for operating an X-ray tube, comprising a grid-controlled switch tube in series with the X-ray tube, an adjustable source of regulating voltage, and control transmitting 10 means including a low voltage high frequency generator connected with said source of regulating voltage and a transformer coupling said generator to the grid of said switch tube to apply

thereto a voltage dependent on said regulating voltage.

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